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## WLAN SERVICES OVER CATV USING CSMA/CA

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/538,508, filed January 26, 2004, which is incorporated by reference, herein, in its entirety.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

[01] The invention relates to an apparatus, system, and method for implementing a new topology for Wireless Local Area Networks (WLAN) and the like, including WiFi systems. More particularly, the invention relates to an apparatus, system, and method that uses cable television (CATV) networks to support WiFi services in homes, businesses, and hotspots such as hotels, hospitals, airports with high capacity and high quality.

#### 2. Description of the Related Art

[02] A WLAN is a flexible data communication system implemented as an extension to, or as an alternative for, a wired LAN.

[03] In a typical WLAN configuration, a transmitter/receiver device, called a wireless access point (AP), connects the user wireless device to the wired network fixed location using standard connections (e.g., Ethernet, cable modem, ADSL, T1, etc.). The

AP receives, buffers, and transmits data between the WLAN and the wired network infrastructure.

[04] A single AP can support a small group of users and can function within ranges of up to several hundred feet. End users access the WLAN through a WLAN modem device.

[05] A related art implementation of a WLAN system is based on a Carrier Sense Multiple Access Collision Avoidance (CSMA/CA) mode. In this mode, each end unit in the network listens to the network to determine whether the path is free for transmission. Only when the path is free for transmission is the end unit allowed to transmit data. If a collision is detected, the data must be transmitted again.

[06] In this configuration, all the units participating in the network must be able to receive all the uplink/downlink data transmitted on the network all the time in the specified coverage area. This is the reason that it is necessary in related art WLAN systems to have an AP at any floor in the building and/or every 100 to 500 feet in range, (to provide full coverage and good receiving signal performance by each of the participants in order to avoid and solve collision problems). This limitation is related directly to the maximum range that can be achieved by the related art WLAN systems

[07] CATV networks have a network architecture designed basically to transmit signals in a top-down or bottom-up manner. In this configuration, two adjacent downstream customers cannot listen to each other. Thus, a conventional implementation of WiFi CSMA/CA is not possible on a CATV network.

#### **SUMMARY OF THE INVENTION**

[08] Illustrative, non-limiting embodiments of the present invention overcome the above disadvantages and other disadvantages not described above. Also, the present invention is not required to overcome the disadvantages described above, and an illustrative, non-limiting embodiment of the present invention may not overcome any of the problems described above.

[09] According to an aspect of the present invention, a WLAN is integrated with a CATV network using Point Coordination Function (PCF). PCF is a centralized, polling-based access mechanism which requires the presence of an Access Point (AP) that acts as Point Coordinator. An AP controller located at the center of the CATV network manages the system. In this mode, the discussion between an end unit and a AP is controlled and no end unit is allowed to transmit data without permission of the AP.

[10] The merger of the WLAN with the CATV networks according to the invention provides improved data quality, better coverage, and better range, while enhancing network capacity to support WiFi services in homes, businesses, and/or hotspot areas such as hotels, airports, hospitals and the like, using a modified CSMA/CA configuration with switching capability for homes and/or hotspots.

[11] According to another aspect of the invention, the CATV network functions as an access element within the analog portion of the WLAN system, namely in its RF propagation-radiation section. The capabilities of existing CATV networks are substantially preserved in the approach, and the WLAN end users terminals do not have to be substantially modified. That is, the signals sent according to the WLAN terminal communications protocol traverse the CATV network, without the necessity for modification.

[12] According to another aspect of the invention, a number of APs can be located at the CATV head-end and/or at the CATV optical node entrance, to be integrated into the CATV network, thus increasing the capacity of the WLAN-CATV network.

[13] One protocol used in the various embodiments of the invention is CSMA/CA, with modified system configuration to support CSMA/CA protocol through the CATV network.

[14] According to another aspect of the invention, the CATV network is modified to permit the communication of the WLAN RF signals without substantial modification, just frequency up and down-conversion to fit the CATV spectrum specifications, and to enable the CATV network to support CSMA/CA protocol.

[15] A conventional CATV network is a two-way network having a tree topology and including cables, amplifiers, signal splitters/combiners and filters. According to one aspect of the invention, the cables and signal splitters/combiners of the CATV network are not modified, but the other elements are. Thus, the invention includes new components for a CATV system that permit multi-band communication. The modified components allow all types of signals (the CATV up and down signals and the WLAN up and down signals) to be carried by the network simultaneously in a totally uncoupled manner. This component modification can be implemented within the component itself (e.g. a modified CATV amplifier that supports the additional signals as well as the traditional CATV signals) or as a separated component (e.g. an additional amplifier that supports all the signals other than the traditional CATV signals).

[16] According to another aspect of the invention, there is provided an Enhanced In Door WiFi Unit (EID-WiFi, also referred to in the FIGs. as PINDU™ for

PASSOVER INDOOR UNIT). The EID-WiFi is a component, which acts as a transmit and receive antenna for the WLAN signals, and as a cable input/output unit for the CATV network.

[17] The EID-WiFi may work in a switching mode where the Uplink and Downlink paths are switched on and off based on activity control. The EID-WiFi may be a dual mode unit. That is to say, the EID-WiFi is capable of receiving and transmitting in modes 802.11b, 802.11g and 802.11a at frequencies of 2.4 GHz and 5.3 GHz correspondingly.

[18] Most of the existing CATV video signals are already limited to frequencies under 750MHz (digital CATV goes up to 860 MHz) while WLAN systems operate above this limit. Moving the WLAN signals to the frequency range of 960 to 1155 MHz enables for the WLAN signals and the CATV signals to coexist.

[19] According to another aspect of the invention, there is provided an Up-Down Converter Unit (UDC). The UDC acts as a frequency converter, converting the AP WiFi signals from:

- a. original RF 2.4 GHz for 802.11b, 802.11g and 5.3 GHz for 802.11a frequencies to 1080 – 1155 MHz Uplink and to 960 – 1035 MHz downlink, (or any other set of uplink, downlink frequencies within the range of 960 to 1155 MHz) and injected into the CATV network; and
- b. the 1080 – 1155 MHz uplink and the 960 – 1035 MHz downlink to the original RF 2.4 GHz for 802.11b, 802.11g and 5.3 GHz for 802.11a frequencies.

[20] The UDC may also convert the AP WiFi signals from original RF 2.4 GHz for 802.11b, 802.11g and 5.3 GHz for 802.11a frequencies to 20 MHz bandwidth in the range of 5 – 45/65 MHz uplink and to 20 MHz bandwidth in the range of 500 – 750/860 MHz downlink, and injected into the CATV network, and vice versa converting the 5 – 45/65 MHz uplink and to 500 – 750/860 MHz downlink to the original RF 2.4 GHz for 802.11b, 802.11g and 5.3 GHz for 802.11a frequencies.

[21] The UDC is equipped with an RF sensor to detect the uplink signals and retransmit them at the downlink path to be received by the other WiFi terminal units. The other WiFi terminal units may sense these signals as part of the Carrier Sense mechanism.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[22] The above and other aspects of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

[23] FIG. 1 illustrates a multi story building with a WLAN over CATV system working within the CATV spectrum at frequencies 5 – 45/65 MHz Uplink and 500 – 750/860 MHz Downlink;

[24] FIG. 2 illustrates a multi-story building with a WLAN over CATV system working out of the CATV spectrum at frequencies 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink;

- [25] FIG. 3 illustrates a multi-story building with a WLAN over CATV system working out of the CATV spectrum at frequencies 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink with multiple AP units;
- [26] FIG. 4 illustrates a Downlink switching configuration to support CSMA/CA over CATV;
- [27] FIG. 5 illustrates an Uplink switching configuration to support CSMA/CA over CATV;
- [28] FIG. 6 schematically illustrates an EID-WiFi according to an exemplary embodiment of the invention;
- [29] FIG. 7 schematically illustrates a simplified schematic view of a WLAN Transport Module (WTM);
- [30] FIG. 8 schematically illustrates a WLAN Entrance Module (WEM);
- [31] FIG. 9 shows a dual mode WEM UDC module, that integrates both 802.11b and 802.11a signals from the APs into the CATV network.
- [32] FIG. 10 illustrates a EID-WiFi switched module UDC;
- [33] FIG. 11 illustrates a dual mode switched EID-WiFi module;
- [34] FIGS. 12 and 13 show the original 802.11b, 802.11g and 802.11a frequencies, respectively;
- [35] FIG. 14 illustrates a bandwidth allocation plan for 802.11b/g non-overlapping channels shifted frequency within the CATV network spectrum;
- [36] FIG. 15 illustrates a bandwidth allocation plan for 802.11b, and 802.11g overlapping channels shifted frequency within the CATV network spectrum;

- [37] FIG. 16 illustrates a bandwidth allocation plan for 802.11a channels shifted to a frequency band within the CATV network spectrum;
- [38] FIG. 17 illustrates a bandwidth allocation plan for three 802.11b/g non-overlapping channels shifted to a frequency band out of the CATV spectrum at frequencies: 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink;
- [39] FIG. 18 illustrates a bandwidth allocation plan for multiple 802.11b/g overlapping channels shifted to a frequency band out of the CATV spectrum at frequencies: 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink;
- [40] FIG. 19 illustrates a bandwidth allocation plan for 802.11a channels shifted to a frequency band out of the CATV spectrum at frequencies: 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink; and
- [41] FIG. 20 illustrates a bandwidth allocation plan for 802.11b/g and/or 802.11a channels working simultaneously out of the CATV spectrum at frequencies: 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink.

**DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS  
OF THE PRESENT INVENTION**

- [42] Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings.
- [43] Aspects of the present invention, and methods for achieving them will be apparent to those skilled in the art from the detailed description of the exemplary embodiments together with the accompanying drawings. However, the scope of the present invention is not limited to the exemplary embodiments disclosed in the specification, and the present invention can be realized in various types. The described exemplary embodiments are presented only for completely disclosing the present

invention and helping those skilled in the art to completely understand the scope of the present invention, and the present invention is defined only by the scope of the claims.

[44] In a first exemplary embodiment of the invention, FIG. 1 shows a multi-story building with a WLAN over CATV system operating within the CATV spectrum 5 – 45/65 MHz Uplink and 500 – 750/860 MHz Downlink. FIG. 1 includes the WLAN Entrance Module (WEM), which converts the original WLAN RF signal to the assigned frequency spectrum to be carried on the CATV network. The EID-WiFi converts the WLAN signals from the assigned frequencies at the CATV spectrum back to their original signals, and differentiates between the CATV signals to be carried to the TV or Set Top Box and the WLAN signals to be transmitted in the customer premises.

[45] Signals from the AP entering at the WEM are converted and distributed through the CATV network. The EID-WiFi is the interface between the upgraded WLAN CATV network and the WLAN unit (e.g., a laptop computer) at the customer premises.

[46] FIG. 2 depicts a multi-story building with a WLAN over CATV system operating out of the CATV spectrum at frequencies: 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink. The WLAN Entrance Module (WEM) shown in FIG. 2, converts the original WLAN RF signal to the assigned frequency spectrum to be carried on the CATV network. The WTM acts as a bypass module to enable transmission of the WLAN signals over the CATV networks without interference between both signals. The WTM is a bypass unit that differentiates between the CATV signals and the WLAN down/ up-converted signals (1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink) at the input/output of each CATV amplifier in the network and combines the signals again at the output/input of each CATV amplifier to be carried on to the next amplifier stage.

[47] The EID-WiFi converts the WLAN signals from the assigned frequencies at the CATV network (out of the standard CATV spectrum) back to their original signals, and differentiates between the CATV signals to be carried to the TV or Set Top Box and the WLAN signals to be transmitted in the customer premises.

[48] Signals from the AP entering at the WEM are converted and distributed through the CATV network. The WTM transports the WLAN signals through the CATV network. The WTM may be installed at any active point of the CATV network, bypassing the trunk amplifiers, line extenders and distribution modules. The EID-WiFi is the interface between the upgraded WLAN CATV network and the WLAN (end user) unit (e.g., a laptop computer) at the customer premises.

[49] FIG. 3 illustrates a multi-story building with a WLAN over CATV system operating out of the CATV spectrum at the frequency range of 1080 – 1155 MHz Uplink and 960 – 1035 MHz Downlink with multiple AP units. As shown in FIG. 3, in this exemplary embodiment, Multiple WLAN Entrance Modules (WEM) are connected to multiple AP's.

[50] Each WEM is connected to an AP which converts the original WLAN RF signal to the assigned frequency spectrum to be carried on the CATV network. The WEM's can convert any AP original frequencies standard (802.11b, 802.11g or 802.11a) to the assigned frequency spectrum.

[51] The AP's WEM's can be from the same standard with the same original frequencies or different original frequencies to support high capacity throughput or from different standards to support all WLAN standards on the CATV network. The WTM, acts as a bypass module to enable transmission of simultaneously multiple WLAN signals

over the CATV networks without interference between both signals. The EID-WiFi converts the WLAN signals from the assigned frequencies at the CATV network (out of the standard CATV spectrum) back to their original signals, and differentiates between the CATV signals to be carried to the TV or Set Top Box and the WLAN signals to be transmitted in the customer premises. Signals from the AP entering at the WEM are converted and distributed through the CATV network.

[52] The WTM transports the WLAN signals through the CATV network. The WTM is installed at any active point of the CATV network, bypassing the trunk amplifiers, line extenders and distribution modules. The EID-WiFi is the interface between the upgraded WLAN CATV network and the WLAN unit (e.g., a laptop computer) at the customer premises.

[53] FIGs. 4 and 5 illustrate Downlink and Uplink switching configuration to support CSMA/CA over CATV. The WEM unit connected to the AP includes a single-pole, double-throw (SPDT) RF switch in the downlink path and a single-pole, single-throw (SPST) RF switch in the uplink path. The EID-WiFi at the customer premises includes SPST switches in the up and downlink path.

[54] In this exemplary embodiment, downlink signals sent from the AP towards the customer premises are detected by the WEM, and the downlink SPDT closes the downlink path to enable transmission of the signal through the CATV network towards the subscriber premises. At the same time, the uplink switch is open to prevent oscillations. At the customer premises, the EID-WiFi's 1, 2, 3, 4, and 5 detect the downlink signal, close the downlink SPST, and open the uplink SPST to prevent oscillations.

[55] Further, End User Terminal No. 1 transmits uplink signals towards the AP. EID-WiFi No. 1 detects the uplink signals, closes the uplink switch, and opens the downlink. Uplink signals are distributed over the CATV network to the AP. At the same time, all the other EID-WiFi's switches are closed at the downlink path and open at the uplink path.

[56] At the WEM, the uplink signal is detected and the uplink switch is closed, while changing the position of the downlink SPDT to loop the uplink signals back towards the CATV network to distribute the looped back uplink signals to the other EID-WiFi's 2, 3, 4, and 5, which are connected to the downlink path. This enables the carrier sense function in the End User WiFi terminals located at EID-WiFi's 2, 3, 4, and 5.

[57] The WEM, with its circuitry for looping the uplink signals back to the CATV network, may be thought of as a means for downstream of uplink signals for a carrier sensing function at the End User WiFi terminals.

[58] A more detailed view of an exemplary EID-WiFi is shown in Fig. 6.

[59] As shown in FIG. 6, the combined WLAN and CATV signals enter at the CATV outlet. The WLAN and CATV signals are differentiated at a Network Coupling Diplexer (NCD). The WLAN signals are up-converted to the original WLAN signal from the CATV assigned spectrum and transmitted in the vicinity of the customer premises, or received from an End User WiFi terminal and down-converted from the original WLAN signals to the CATV assigned frequency spectrum. The TV signals are connected to the TV set (or any other suitable device) through the TV set outlet.

[60] FIG. 7 illustrates a WTM according to an exemplary embodiment of the invention. The combined WLAN and CATV signals enter the WTM. Through the high-

pass / low-pass filter (HP/LP), the signals are distributed into two different paths; one path carries the CATV signals and the other carries the WLAN signals.

[61] At the end of the path, the signals are combined again through the HP/LP to be carried through the network. That is, the combined WLAN and CATV signals enter at the entrance of the LP/HP diplexer. The diplexers each differentiate between the CATV signals and the WLAN signals. The CATV signals 5 - 750MHz (860MHz) are carried through the LP filter to the CATV amplifier.

[62] The output signals from the CATV amplifier are carried to an additional LP filter to be combined again with the WLAN signals. The WLAN signals are carried to/from the HP output to the WLAN filter, and the WLAN filter differentiates between the up-link and down-link signals to be amplified by the amplifiers to balance the power budget along the pass.

[63] The WLAN signals from the amplifiers are connected to the HP/LP filters via the fibers, to be combined with the CATV signals and carried on through the network. Note that in exemplary embodiments, the WTM can be used simultaneously for forwarding WLAN signals as well as other signals, such as cellular signals.

[64] FIG. 8 illustrates a WEM according to an exemplary embodiment of the invention.

[65] The WEM is an interface between the WLAN Access Point (AP) and the CATV signals. Downlink WLAN signals from the AP are down-converted to the assigned CATV spectrum and Uplink WLAN signals are up-converted from the assigned CATV frequency spectrum to the original WLAN frequencies. The WEM down-converts, for example, the original 802.11b, or the 802.11a signals received from the AP

to intermediate WiFi frequencies to be carried on the CATV network and up-converts the intermediate WiFi frequencies carried on the CATV network to the original 802.11b or 802.11a to be received by the AP.

[66] The WEM depicted in FIG. 8 is a single band Up/Down Converter that converts the WLAN signals from their original signals i.e. 2.4 GHz (due to 802.11b) and or 5.3 GHz (due to 802.11a) to any frequency bandwidth in the frequency band of 960 – 1035 MHz, 1080 – 1155 MHz and/or 5 – 45/65 MHz 500 – 750/860 MHz. The WEM module converts TDD downlink signals to FDD downlink signals to be transmitted over the CATV network, and uplink FDD signals coming from the CATV network to uplink TDD signals to be transmitted to the AP.

[67] FIG. 9 depicts a dual band WEM UDC according to an exemplary embodiment of the invention. The dual band WEM enables the simultaneous carrying of both 802.11b and 802.11a signals on the CATV network to, for example, the customer premises. Each band is converted to a different portion of the spectrum in the CATV network. For example, 802.11b may be converted to a 20 MHz bandwidth uplink and a 20 MHz downlink within the frequency range of the CATV, (960 – 980 MHz, and 1080 – 1100 MHz). Also, 802.11a may be converted to another 20 MHz bandwidth uplink and a 20 MHz downlink within the frequency range of the CATV, (1000 – 1020 MHz, and 1120 – 1140 MHz). In the embodiment of this Figure, for example, both paths may be 5.3Ghz..

[68] FIG. 10 illustrates a EID WiFi UDC according to an exemplary embodiment of the invention. The EID WiFi down-converts the original 802.11b, or the 802.11a signals received from the end user terminal to the assigned CATV network

frequencies (960 – 1035 MHz for example), and up-converts the WiFi signals carried on the CATV network (1080 – 1155 MHz) to the original 802.11b or 802.11a signals to be transmitted to the end user terminal. The EID WiFi is working in switch mode, and the uplink and downlink switches are controlled by the local control logic, according to the sensing of uplink and downlink signals.

[69] In the embodiment of FIG. 10, for example, the EID-WiFi switched module UDC converts the FDD Downlink WLAN signals received from the CATV network in the frequency band of 960 – 1035 MHz and/or 500 – 750/860 MHz to TDD Downlink signals to be transmitted at the customer premises using the WiFi frequencies (2.4GHz and/or 5.3GHz) and converts back TDD uplink signals received from the customer premises in the WiFi frequency band (2.4GHz and/or 5.3GHz) to FDD uplink signals to be transmitted on the CATV network at the frequency band 1080 – 1155 MHz and/or 5 – 45/65 MHz towards the AP.

[70] FIG. 11 shows a dual band EID-WiFi UDC. The dual band EID WiFi unit enables the reception and transmission of both 802.11b and 802.11a, simultaneously, on the CATV network and to the end user. This unit enables the use of both standards simultaneously on the network. For example, 802.11b may be converted to 20 MHz bandwidth uplink, and 20 MHz downlink within the frequency range of the CATV, (960 – 980 MHz, and 1080 – 1100 MHz). 802.11a may be converted to another 20 MHz bandwidth uplink, and 20 MHz downlink within the frequency range of the CATV, (985 – 1005 MHz, and 1105 – 1125 MHz).

[71] FIGs. 12 and 13 illustrate the original 802.11b, 802.11g and 802.11a frequencies. Note that 802.11b and 802.11g share the same frequency channels.

[72] FIG. 14 illustrates a frequency chart of the original 802.11b, and 802.11g non-overlapping frequencies. These original, non-overlapping frequencies are shifted to downlink and uplink frequencies such that the WLAN WiFi signals can be carried on the CATV network spectrum.

[73] FIG. 15 illustrates a frequency chart of the original 802.11b, and 802.11g overlapping frequencies. These original overlapping frequencies are shifted as needed to downlink and uplink frequencies such that the WLAN WiFi signals can be carried on the CATV network spectrum.

[74] FIG. 16 illustrates a frequency chart of the original 802.11a frequencies. These original frequencies are shifted as needed to downlink and uplink frequencies such that the WLAN WiFi signals can be carried on the CATV network spectrum.

[75] FIG. 17 illustrates one bandwidth allocation plan for 802.11b, and 802.11g non-overlapping channels (shifted frequency out of the CATV spectrum) at frequencies 1080 – 1155 MHz for Uplink and 960 – 1035 MHz for Downlink.

[76] FIG. 18 illustrates one bandwidth allocation plan for 802.11b, and 802.11g of overlapping channels (shifted frequency out of the CATV spectrum) at frequencies 1080 – 1155 MHz for Uplink and 960 – 1035 MHz for Downlink.

[77] FIG. 19 illustrates one bandwidth allocation plan for 802.11a channels (shifted frequency working out of the CATV spectrum) at frequencies 1080 – 1155 MHz for Uplink and 960 – 1035 MHz for Downlink.

[78] FIG. 20 illustrates one bandwidth allocation plan for 802.11b, and 802.11g and/or 802.11a channels working simultaneously (out of the CATV spectrum) at frequencies 1080 – 1155 MHz for Uplink and 960 – 1035 MHz for Downlink.

[79] Although exemplary embodiments of the present invention have been described for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims, including the full scope of equivalents thereof.